Estimating carbon sequestration in a Great Lakes coastal wetland using radiometric dating

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ABSTRACT

Wetlands constitute a large soil carbon pool and play an important role in global carbon cycles. Recent sediment accumulation in wetland soils can be estimated using radiometric dating techniques of ^{137}Cs fallout. Extracted sediment cores from Old Woman Creek, a 56-ha freshwater estuarine wetland on the southwestern shore of Lake Erie, Ohio, has a peak in ^{137}Cs concentration that indicated an accumulation of 18 cm of sediments in the last 42 years. The sedimentation rate in Old Woman Creek wetland is then 0.4 cm yr^{-1}, accumulating 29.7 tons of sediment per hectare each year. Carbon content of the soil in this wetland was also determined. The carbon density of the sediment was 53 gC kg^{-1} soil, with 80% as organic carbon. From these results, it is estimated that Old Woman Creek wetland has accumulated about 80 tons C yr^{-1} over the last 42 years at a rate of 1.42 tonsC ha^{-1} yr^{-1}. This number is comparable to estimates from other river-dominated wetlands in Ohio.

INTRODUCTION

Wetlands are depositional environments that function as sinks for sediments and nutrients (Mitsch and Gosselink, 2007). Waterlogged conditions and high productivity give wetlands the ability to retain and sequester large amounts of organic matter in the soil, representing a significant terrestrial carbon pool and playing an important role in global carbon cycles and climate change. Most studies on carbon sequestration rates in wetlands are focused on boreal climates; little is known about their role on temperate and tropical climates, due in part to the difficulty of establishing a baseline to estimate accumulation rates.

Radiocesium (^{137}Cs), a man-made fallout radionuclide worldwide distributed as consequence of deposition from atmospheric nuclear weapon tests, had its maximum deposition in the year 1964 (Smith et al., 2000). Once in the soil, ^{137}Cs is strongly fixed by clays and the organic fraction (Ilus and Saxén, 2005). Its deposition pattern is found in the soil profile, and the peak of ^{137}Cs activity in extruded soil cores is used as a marker for its deposition peak in 1964 (Graham et al., 2005). The analysis of ^{137}Cs activity can be widely used to determine accretion rates and deposition chronologies, and it can be especially successful in depositional environments like wetland floodplains.

The overall goal of our study is to estimate recent sediment deposition and carbon sequestration rates in soils of temperate and tropical wetlands using radiometric dating with ^{137}Cs. The objective of this study is to demonstrate that radiocesium can be used as a reliable tool for defining a baseline to estimate accumulation rates and determine carbon sequestration rates in a coastal Lake Erie wetland.

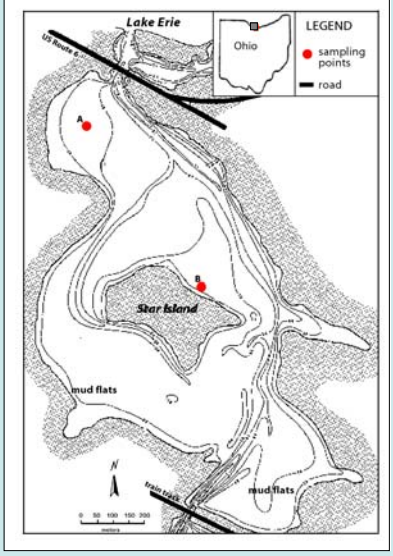
MATERIALS AND METHODS

Old Woman Creek is a 56-hectare freshwater coastal wetland (Figure 1) located in Huron County, Ohio, on the southwestern shore of Lake Erie. It is connected to the Lake, and water and sediment movement is primarily driven by seiches from the Lake Erie and by stream drainage from the catchment (Herdendorf and Hume, 1991).

Two 34-cm long and 7-cm diameter soil composite samples were taken with a sediment sampler (Figure 2) in representative sites of the wetland, in August 2006. Sample A was extruded in a permanently flooded site, where water lotus (*Nelumbo lutea*) was present. Sample B was taken in a fluctuating water level site, where cattail (*Typha angustifolia*) was dominant. Each composite sample consisted of three sediment cores spaced within 40 cm in order to include variation of ^{137}Cs deposition in the area (Isaksson et al., 2001). Extruded cores were immediately sectioned into slices 2 cm thick, and corresponding layers in the three cores of the composite sample were pooled into one sample per layer.

Sediment samples were oven-dried at 105ºC for three days and weighed to determine bulk density. Dried samples were passed through a 2-mm sieve and homogenized.

To determine the depth of the layer in the sediment core corresponding to the year 1964, layers were analyzed in a High Efficiency Germanium Detector (Canberra) by gamma spectroscopy at 661.7 keV for ^{137}Cs. Once the amount of sediment accumulated in the last 42 years was defined, its organic and inorganic carbon content was analyzed in a total organic carbon analyzer (TOC-V by Shimadzu).



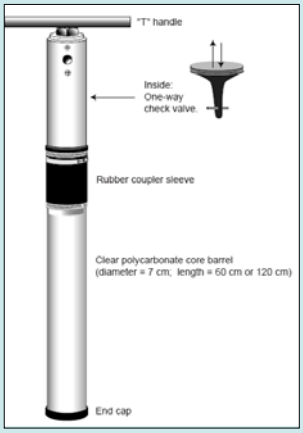
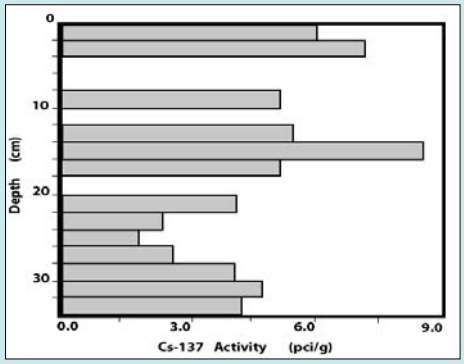


Figure 1 (Left). Bathymetric map of Old Woman Creek National Estuarine Reserve (adapted from Herdendorf and Hume, 1991), with location of sampling points.

Figure 2 (Above). Universal Head sediment sampler.

RESULTS

The peak of ^{137}Cs in the wetland soil with depth corresponding to 1964 in the two cores is located at 16-18 cm deep in Old Woman Creek (Figure 3). The total carbon (organic and inorganic) in the first 20 cm was measured and its variation along the soil profile in the two cores is represented in Figure 4. Rates of sediment accretion and carbon sequestration are summarized in Table 1. Carbon values are given in total carbon terms, *i. e.*, organic carbon plus inorganic carbon. Organic Carbon was about 80% of the Total Carbon accumulated in the wetland soil in both sites. It can be inferred from the obtained results that the wetland is accumulating a total of 80 tonsC/year in its 56 hectares.



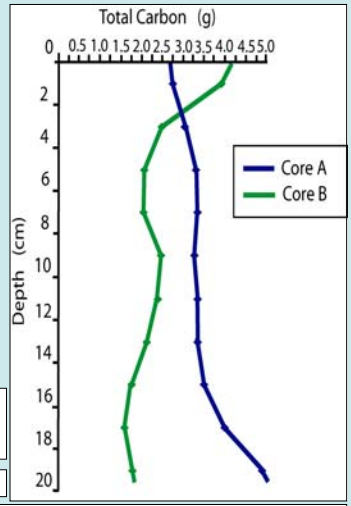


Figure 3 (Above). Variation of ^{137}Cs activity in the sediment with depth.

Figure 4 (Right). Total carbon measured in each layer of sediment in cores A and B.

Table 1. Sedimentation and carbon sequestration for cores A and B.

	1964 layer location (cm)	annual sediment accretion (mm yr^{-1})	sediment accumulation (g)	annual sediment accumulation (tons ha^{-1}yr^{-1}) *	annual carbon accumulation (gC yr^{-1})	carbon density (gC kg^{-1}soil)	carbon sequestration rate (gCm^{-2}yr^{-1}) *
Core A	16	3.8	363.9	25.6	0.62	71.8	160
Core B	18	4.2	565.3	34.2	0.48	35.5	124
mean	17	4.0	464.6	29.7	0.55	53.6	142

* calculation for the complete 56-ha wetland

DISCUSSION AND CONCLUSIONS

A ^{137}Cs peak was found at the same depth in two very different locations of the wetland, demonstrating the reliability of the method and the validity of the results. The finding of 4 mm/year sediment accretion rate is also supported by a previous study at Old Woman Creek Reserve (Wilson et al., 1997) that estimated a sediment accumulation rate of 5mm/year in the last 50 years in this wetland. In addition, our carbon accumulation rate of 142 gC m^{-2} yr^{-1} compares well with carbon sequestration rates measured for similar freshwater wetlands (Table 2).

Table 2. Carbon sequestration rates in wetlands. Literature values compared to the results obtained in the present study at Old Woman Creek. Comparison data from Mitsch and Gosselink (2007).

wetland type	gC m^{-2}yr^{-1}
General range for wetlands	20 - 140
Peatlands, North America	29
Created temperate marshes, OH	190
Restored prairie potholes, North America	305
Old Woman Creek, OH	142

Differences in the carbon profile are a consequence of the hydrological conditions on the two sites. Anaerobic conditions due to the permanent presence of water in site A enhance organic matter accumulation and provide ideal conditions for carbon sequestration. Site B is characterized by shifting wet and dry conditions that lead to fluctuations in the carbon pool, due to oxidation and disturbance during aerobic (dry) periods.

This study demonstrates that, despite being a delicate and sensitive method, radiometric dating with ^{137}Cs can be used successfully to estimate sediment accretion and carbon sequestration rates in freshwater wetlands. This method can be a useful tool to define the role of wetlands as carbon sequestering systems. Carbon sequestration is a key process that counteracts the increasing carbon emissions to the atmosphere that are leading to global warming and climate change. If carbon sequestration rates in wetlands are better defined, wetlands might become an important mitigation tool for carbon managers and policy makers to reduce net carbon emissions worldwide.

AKNOWLEDGEMENTS

Support for this project came from the U.S. Environmental Protection Agency (grant EM-83329801-0), the Wilma H. Schiermeier Olentangy River Wetland Research Park, and The Ohio State University School of Environment and Natural Resources. Old Woman Creek State Nature Preserve (Frank Lopez, manager) aided with research permissions and logistics. Thanks to all those, including the good friends and colleagues, who helped in the field and advised us in the experimental design.

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